

**PREVALENCE OF GASTROINTESTINAL PARASITES
OF SEMI-CAPTIVE ORANGUTANS (*PONGO
PYGMAEUS*) IN BUKIT MERAH ORANG UTAN ISLAND,
PERAK, MALAYSIA**

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**UNIVERSITI SAINS MALAYSIA
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PYGMAEUS*) IN BUKIT MERAH ORANG UTAN ISLAND,
PERAK, MALAYSIA**

by

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**Thesis submitted in fulfillment the requirements
for the degree of
Master of Science**

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**KADAR PREVALENS PARASIT GASTROUSUS ORANG UTAN (*PONGO
PYGMAEUS*) DI PULAU ORANG UTAN, BUKIT MERAH, PERAK,
MALAYSIA**

ABSTRAK

Kajian ini dijalankan untuk memeriksa prevalens parasit gastro usus dalam dua puluh satu ekor orang utan (*Pongo pygmaeus*) separa kurungan di Pulau Orang Utan, Bukit Merah, Perak. Dua pensampelan dilakukan dengan purata tiga kali bacaan dalam tempoh satu tahun (Disember 2014-Disember 2015). Lima kaedah digunakan untuk kajian parasit gastro usus, parasit protozoa dan parasit telur cacing. Kaedahnya ialah bacaan McMaster, pemeriksaan langsung, larva kultur, pengapungan dan pemendapan. Bagi kajian berlainan pula, pensampelan pastura dilakukan menggunakan kaedah modifikasi Baermann untuk mendapat larva infektif dan pemeriksaan kulit orangutan telah dilakukan untuk ektoparasit. Juga, keberkesanan antelmintik telah dijalankan kepada orang utan dengan menggunakan ivermektin, albendazol dan *Clinacanthus nutans*. Hubungan antara keadaan iklim dan parasitisme juga dikaji sepanjang penyelidikan. Sembilan endoparasit telah direkodkan iaitu *Strongyloides fuelleborni*, *Strongyloides stercoralis*, *Trichostrongylus* spp., *Cooperia* spp., *Strongyle* spp., *Oesophagostomum* spp., *Ascaris lumbricoides*, *Enterobius* ssp., dan satu protozoa *Balantidium coli*. Hanya satu ektoparasit direkodkan iaitu *Haemaphysalis* ssp.. Prevalens parasit gastro usus dalam perbandingan kepada kumpulan umur menunjukkan signifikasi terutama orang utan subdewasa memberi jumlah jangkitan parasit tertinggi. Prevalens parasit gastro usus dalam perbandingan kepada kumpulan jantina tidak

menunjukkan signifikasi. Bacaan epg menunjukkan korelasi positif bersama hujan. Empat helmin telah direkodkan dalam pensampelan pastura dan spesies yang ditemui merupakan spesies yang sama ditemui di dalam gastrousus orang utan; *Trichostrongylus* spp., *Strongyloides* spp., *Cooperia* spp. dan *Oesophagostomum* spp.. Korelasi dengan iklim menunjukkan bahawa helmin dalam pastura berkaitan secara songsang dengan hujan. Ivermektin menunjukkan keberkesanan tertinggi dengan pengurangan 100% kiraan telur najis, albendazol dengan pengurangan sebanyak 98.67% dan *Clinacanthus nutans* dengan pengurangan sebanyak 15.43%.

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ABSTRACT

This study was conducted to examine the prevalence of gastrointestinal parasites in twenty-one semi-captive orangutans (*Pongo pygmaeus*) in Bukit Merah Orang Utan Island, Perak. Samples were collected twice monthly with three replicates in period of one year (December 2014-December 2015). Five methods were used to screen for gastrointestinal parasites, protozoan parasites and parasitic eggs of worm. The methods were McMaster's technique, direct screening, larvae culture, flotation and sedimentation. In another study, pasture samples were collected to recover the dominant infective larvae using modified Baermann method and skin examination was done for ectoparasite. Also, anthelmintic efficacy was tested on orangutans by using ivermectin, albendazole and *Clinacanthus nutans*. The relation between climatic condition and levels of parasitism were also monitored throughout the research. Nine endoparasites were recorded which are *Strongyloides fuelleborni*, *Strongyloides stercoralis*, *Trichostrongylus* spp., *Cooperia* spp., *Strongyle* spp., *Oesophagostomum* spp., *Ascaris lumbricoides*, *Enterobius* sp., and a protozoa of *Balantidium coli*. Only one ectoparasite was recovered which is *Haemaphysalis* ssp.. Prevalence of gastrointestinal parasites in comparison to age groups were significantly different with sub-adults' orangutans give the highest number of parasites infection. Prevalence of gastrointestinal parasites in comparison to sex group male and female was not varied significantly. Epg number showed positively correlated with rainfall. Four helminthes were recorded in pasture

sample and the species were usually found in gastrointestinal of orangutans; *Trichostrongylus* spp., *Strongyloides*spp., *Cooperia* spp. and *Oesophagostomum* spp.. Correlation with climate showed that helminthes in the pasture were inversely related with rainfall. Ivermectin showed the highest efficacy with reduction of 100% fecal egg count, albendazole with reduction of 98.67% and *Clinacanthus nutans* with reduction of 15.43%.

CHAPTER I

INTRODUCTION

A study on gastrointestinal parasite is important for the management of critically endangered orangutans (*Pongo pygmaeus*) and the safety of animal keepers in the conservation because many of these parasites are potentially zoonotic. The presence of certain type of parasites could interfere with their physiological processes to such degree that they would be unable to produce offspring and threaten their life (Smyth, 1994). Biomedical researchers have previously ignored the importance of information regarding parasites of non-human (Ananias *et al.*, 1997). Somehow, the role played by wild animal population that acts as hosts of parasites of the emerging zoonotic pathogens has attracted the attention of animal conservation research (Wolfe *et al.*, 1998).

Captive orangutans can be at greater risk of contracting and spreading pathogens and parasites than orangutans in the wild when they are often kept in close contact with humans and other animals (Ott- Joslin, 1993). An organism infected by parasites can upset the systems which maintain health, interfering with the normal processes and reduce valuable energy gained from hard-earned foodstuffs. Moreover, information on parasite threats is globally limited. The gap analysis of parasite investigation in non-human primate of orangutans found in Southeast Asia is one of three regions in the world with the most deficient sampling.

In recent years, researchers have studied the anthelmintic activity of traditional medicinal plants against nematodes as promising control measures, particularly plants that have no toxic effects on animal hosts. As anthelmintic resistance is widely overspread, the use of medicinal plants gives advantages as they are nutritious, cheap and has shown no evidence of the development of resistance to medicinal plants among nematodes (Athanasiadou *et al.*, 2007; Fajimi and Taiwo, 2005).

Based on the aforementioned information, the unique approach of this study is to investigate whether complex aspects of ethology and ecology influence parasite infections and how parasite may have impact on whole ecosystem in the conservation center of Bukit Merah Orang Utan Island, Perak, Malaysia (BMOUI) through three main studies. First, the annual seasonal variations in the egg counts of nematodes and their correlations with the climatic conditions were observed. Second, the pasture larval count technique that supports population dynamic and epidemiological studies under different climatic conditions. Lastly, the anthelmintic efficacy of nematode used in the conservation center was assessed with comparison of medicinal plant as alternative solution. All the investigations can be used for management strategies of the conservation center.

The present research aims to:

1. To study the prevalence of gastrointestinal parasites, protozoan and ectoparasites of the semi-captive orangutans in BMOUI in comparison to host gender (male and female) and host age (adult, sub-adult and juvenile). Study period: December 2014- December 2015
2. To compare the seasonal variations in egg counts of nematodes in semi-captive orangutans during dry and wet seasons, and to determine their correlations with the climatic conditions (rainfall, humidity and temperature). Study period: December 2014- December 2015
3. To determine the parasitic infestation in soil of the island exhibits by the method of pasture larval count in five exhibits. Study period: December 2015-June 2016
4. To investigate the efficacy of anthelmintic drugs that commonly used in the conservation center (ivermectin and albendazole) with anthelmintic activity of Sabah snake grass (*Clinacanthus nutans*) raw leaves to nematode eggs reduction. Study period: July 2016- August 2016

CHAPTER II

LITERATURE REVIEW

2.1 Orangutan (*Pongo pygmaeus*)

Pongo abelii, *Pongo pygmaeus* and *Pongo tapanuliensis* are the three subspecies of orangutans. They are known to be the closest phylogenetic relatives to humans as they are also in the family of Hominidae. Previously they are known as *Simia satyrus* (von Koenigswald, 1982). The taxonomic classification of Bornean orangutan is as follows:

Kingdom	: Animalia
Phylum	: Chordata
Class	: Mammalia
Order	: Primates
Family	: Hominidae
Sub-family	: Pongidae
Genus	: <i>Pongo</i>
Species	: <i>P. pygmaeus</i> (Bornean) (Linnaeus, 1760) <i>P. abelii</i> (Sumatran) (Lesson, 1827) <i>P. tapanuliensis</i> (Tapanuli) (Nater <i>et al.</i> , 2017)
Subspecies	: <i>Pygmaeus pygmaeus pygmaeus</i> <i>Pygmaeus pygmaeus mario</i> <i>Pygmaeus pygmaeus wurmbii</i> (Warren <i>et al.</i> , 2001)

2.2 Life cycle and morphology of orangutan

Both males and females orangutans have average lifespan of 40-50 years of age (Leighton *et al.*, 1995). Males are generally solitary, and females often live together with their infant or juvenile offspring. Also, females orangutans have mean duration of eight years of interval interbirth, which recorded as the longest in any primate (Galdikas and Wood, 1990). Additional to that, the mother and infant bond is very strong, making the offspring is clingy and dependent to their mother for six years and more (Rodman, 1988). Females are ready to become a mother until approximately fifteen years of age (Galdikas, 1982). Hence, they can only produce for to five surviving offspring per mother, and this was reported as the lowest reproductive potential of any mammal (van Shaik, 2001).

Orangutans achieve puberty mostly males at the age of 10 and females at the age of 7. Adult orangutans are significantly different in size between male and female orangutans. Males are approximately 45 to 100 kg in weight while females are around 35 to 50 kg of weight. They have a long arm width that when they stretch their arms is about 2 meters that eventually longer than their standing height which only 1.5 meters. These long hands help them in their lifestyle for brachiation.

For Bornean orangutans, they have brown-black hair color and Sumatran having more reddish hair color. Bornean orangutans (Plate 2.1) have more a messy look compared to Sumatran. Sumatran orangutans (Plate 2.2) usually have a thick silky hair, bearded, moustache and cheek pad are always present, on the other hand Bornean have less hair and short with skin is clearly visible. While *P. tapanuliensis* has frizzier type of hair compared to both Bornean and Sumatran orangutans (Plate 2.3) (Nater *et al.*, 2017)



Plate 2.1. Bornean orangutan with darker color

(Source: <http://orangutan.or.id/orangutan/>)



Plate 2.2. Sumatran orangutan with more reddish color

(Source: <http://www.onegreenplanet.org/environment/orangutan-and-the-man-who-is-helping-save-them-with-a-camera/>)



Plate 2.3. Tapanuli orangutan with frizzier hair

(Source: <https://secondnexus.com/environment/tapanuli-orangutans-endangered/>)

2.3 Habitat and population distribution of Bornean orangutans

Orangutans usually found living in the primary and secondary forest of dipterocarp forest, peat swamp and freshwater swamp forest (Rijksen and Meijard, 1999). The main reason of them habituating these habitats is because food availability to support the population. This can be seen in peat swamp forest that provide sufficient food and less fluctuates of food scarce period (Morrogh-Bernard *et al.*, 2008).

The man of forest are endangered apes with its population distribution is restricted to the south-East Asian islands of Borneo and Sumatra. At present time, orangutans are only found in Sumatra, Kalimantan, Sabah and Sarawak. The Borneo is split between Kalimantan, Indonesia and Malaysian territory of Sabah. In 1997, the orangutan population estimate for Bornean orangutans (*Pongo pygmaeus*) was only 7%

of the population in 1900. Whereas, Sumatran population in 2002 was 4% of the population in 1900 (Rijksen and Meijaard, 1999). Furthermore, Sumatran orangutan (*Pongo abelii*) was listed in IUCN Red List for critically endangered species (IUCN, 2004).

2.3.1 Habitat lost

The drastic decline of orangutans since the last century were attributed to several causes mainly from orangutan poaching by humans, but recently due to habitat destruction. As well, due to rapidly shrinking of lowland forest and increasingly fragmented on both Borneo and Sumatera islands, reliance on only to these forests as habitat is unlikely to be the suitable strategy for prevention of orangutan extinction (Marshall *et al.*, 2006). Orangutans need large contiguous areas to continue population survivals. These large-bodied, slowly-reproducing primates require large areas, and because of that population densities still remain low even in suitable habitat (Rijksen and Meijaard, 1999).

Destruction of the forests into logged and secondary forests are mainly for the development of timber industry and palm oil plantation. This has caused orangutans population densities to decline in a long term even though they exhibit high behavioral and dietary flexibility that allows them to continue living in secondary logged forest (Lackman-Ancorenaz *et al.*, 2001). Not only orangutans, but all current wild populations have already been deemed to be at their carrying capacity Bornean orangutan with 104,000 individuals of Bornean orangutans and 14,000 Sumatran, orangutans are believed to act as the umbrella species for the forest population (Singleton and Aprianto, 2008).

2.4 Orangutan as flagship and umbrella species

Where people may not give much attention to conservation rhetoric, many already acknowledge that protecting the man of forest and its environment is an important task. Orangutan has extraordinary potential for conservation because its ability to attract and capture the attention of general public, hence orangutans is presented as flagship ambassador because of their charismatic mega fauna that draw a great deal to the rainforests of Indonesia and Malaysia. In addition to its role as a flagship species, orangutans are also known as an umbrella species.

Umbrella species is whose that home range and habitat requirements are large enough that when it is protected, the entire structure of biological diversity of its range will automatically protected (Stork, 1995). If there is an orangutan population at regular density, the area is likely to host at least five other primates' species, at least five hornbill species (Family Bucerotidae), at least fifty different fruit tree species and fifteen different lianas (Rijksen and Meijaard, 1999).

The orangutan with its predominantly arboreal existence and generalized frugivory, equate to no other species being able to match it in functional representation of the rainforest. Hence, orangutan serves as flagship and an umbrella species can greatly help the conversation cause. To start a conversation project targeted its flagship species have higher rate of success according to Kruger (2005).

2.5 Conservation of orangutans

About 60% of the animals are surviving outside of protected areas, in secondary forests that are exploited by indigenous communities and local industries, resulting in a direct conflict of interest between the needs for preserving this iconic species and the needs for human development (Ancrenaz *et al.*, 2004).

To achieve a normal behavior for these primates, most conservation and rehabilitation centers provide some naturalistic components into their habitats including ropes, climbing structures, old trees and plenty of food to stimulate these arboreal species its foraging behavior (Kuhar *et al.*, 2010). Superior management practices that follows the guidelines designed to optimize the health and well-being of primates has increased the survivorship of captive orangutans over the years compared to free ranging orangutans (Wich *et al.*, 2009).

Even so, there are still lack of information on diseases and parasites of captive orangutans to reveal the transmission and impacts of pathogens of human origin (Hopkins and Nunn, 2007) especially helminth, arthropod parasites and protozoa (Gillespie *et al.*, 2004). Because of this, this has become a major limiting factor in health management of every conservation centers (Hotex *et al.*, 2008).

In nature wherewild animals live on large areas they have less exposure to parasitism and low genetic resistance towards it. When these wild animals are kept in captivity, their exposure of parasites heighten and pose a serious threat to them. Parasitic infection aggravate will occasionally causing sudden declined to endangered species and unexpected declines in abundance (Muoria *et al.*, 2005). In conclusion, knowledge of

diseases needs to be gained, especially when wild species are reintroducing into captivity.

2.6 General overview of common parasites infesting primates

Parasites have been implicating to cause serious health threat to captive and free-ranging wildlife (Gillespie, 2006). While wildlife plays crucial roles as sources, amplifiers and reservoirs of emerging human and livestock pathogens (Daszak *et al.*, 2000; Greger, 2007), having disease not only just any mild or severe but also a big impact to the socio-economy may involve. Infectious diseases are the third most important driver of population decline of wildlife after hunting and habitat degradation.

Gastrointestinal parasites affect its host directly and indirectly; directly through pathologic affects and indirectly by lessen its host condition (Dobson and Hudson, 1992). Blood loss, tissue damage, spontaneous abortion, congenital malformation and death are severely causes by gastrointestinal parasites (Gillespie, 2006). Hence, gastrointestinal parasites resulted in clinical diseased. A study of gastrointestinal parasites is important for the management of the safety of the whole primate colony and individual because many of these parasites are potentially zoonotic. Many studies have documented that parasites are infectious especially from non-human primates to human (Hamlen and Lawrence, 1994; Miller *et al.*, 1990).

Primates in wildlife have been demonstrated to naturally have the ability to infect by human and life stock with huge number of zoonotic pathogens. This is because their close proximity that causing a high chance to transmit diseases or parasites to human and life stock. As compared to species that would not normally come into

contact with pathogens, thus causing lesser infection cases (Bengis *et al.*, 2004; Emikpe *et al.*, 2007). Even so, it is possible for helminths to coexist with host without obvious behavior change, in some cases consequent pathology are severe (Muller *et al.*, 1996).

It has documented by Altizer *et al.* (2007) that threatened species of primate parasites that live in a large area harbor fewer parasites such as helminthes, protozoa, arthropods and also bacteria and viruses. While non-threatated primate species that live in a smaller area will have higher parasite exchange. Besides that, many information on parasites infections comes from non-invasive fecal sampling method concerning endoparasites loads in primate and those data are scarce as compared to studies of other species. Heavy infestations can cause death to the host animals (Rasambainarivo and Junge, 2010).

2.6.1 Parasites of orangutan

Generally, there is few information available for orangutan parasites studies especially in semi-captive and captive condition. New information regarding the parasites are very valuable because there is less information especially on parasites infecting orangutans in their natural habitat. The first study published on parasites of free-ranging Sumatran orangutans was documented by Rijksen (1978). Then, more research later was done on parasites in the wild habitat, captive and newly reintroduced orangutans as published by Collet *et al* (1986).

A study by Djojoasmoro and Purnomo (1998) from different group of orangutans recovered *Oesophagostomum* sp., *Trichuris trichura*, *Strongyloides fuelleborni*, *Enterobius* sp., *Ascaris lumbricoides* and *Trichostrongylus* sp. . The highest

prevalence of all was *Strongyloides fuelleborni*, that usually found in young orangutans during reintroduction. According to Nurcahyo and Prastowo (2013), when orangutans from the tree have contact with the ground to retrieve food is when reinfection from the feces orangutans who suffered with *Strongyloides fuelleborni* could occurred. The same finding by Moresco-Pimental (1997) also recorded high prevalence of *Strongyloides* sp. in wild orangutans from Suaq Belimbing in Northern Sumatra.

One of the more detailed study done on orangutans parasites was published by Foitava (2002). The study was done in Sumatra and recorded ten species of parasites including the first finding of *Chilomastrix mesnelii* and *Endolimax nana* in wild and semi-captive orangutans. The highest parasites recorded was *Oesophagostomum* sp., *Strongyloides* and *Balantidium coli*. Also, another study done by Foitová (2005) described protozoa parasites of *Entamoeba hartmanni*, *Dientamoeba fragilis* and *Cryptosporidium* sp. infecting wild and semi-wild orangutans. In addition, Foitová *et al.* (2006) and Mul *et al.* (2007) recorded semi-wild orangutans harbor higher prevalence of metazoan parasites than wild orangutans and *Strongyloides* sp. had a higher prevalence in captive than in free-ranging orangutans in comparison with Tanjung Puting (Central Kalimantan, Borneo) and Bukit Lawang (North Sumatra), wild orangutans from Ketambe (South-east Aceh, Sumatra) due to its life cycle that has three routes of infection (Plate 2.4).

Apart from endoparasites, ectoparasites are known cause diseases and stress to orangutans. Ticks are obligate hematophagous ectoparasites of vertebrates including amphibians, reptiles, birds and mammals. They act as vector for many pathogens as well and attracted attention because of their medical and veterinary importance (Jongejan and

Uilenberg, 2004). The hard tick *Haemaphysalis* sp. which also infest primate, was widely distributed in China, New Zealand, Japan, and Australia (Teng and Jiang, 1991). They also able to transmit several diseases such as theileriosis (Li *et al.*, 2009), babesiosis (Ros-Garcia *et al.*, 2013), Rickettsia (Zou *et al.*, 2011) and tick-borne encephalitis virus (Kovalev and Mukhacheva, 2013).

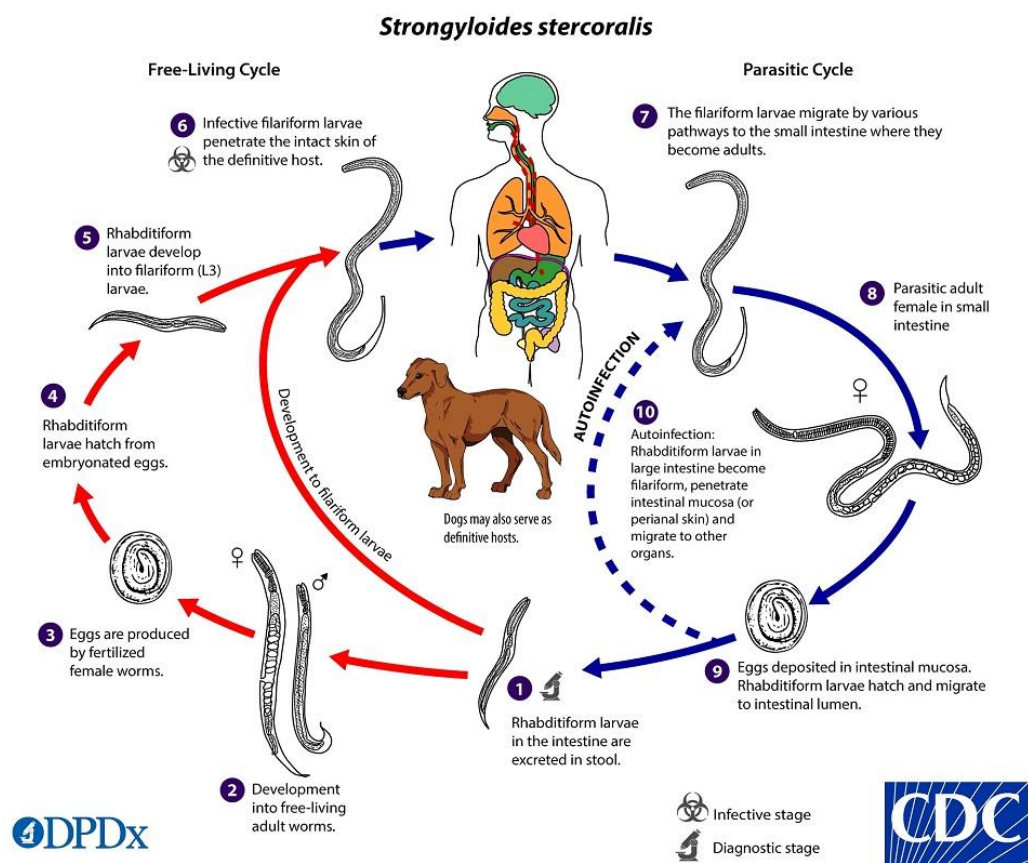


Plate 2.4. *Strongyloides stercoralis* life cycle that has three routes of infection

(Source: <https://www.cdc.gov/parasites/strongyloides/biology.html>)

2.6.2 Protozoan parasites

In a study of captive, semi-captive and wild *Pongo pygmaeus*, the prevalence recorded by Labes *et al.* (2009) showed that *Entamoeba histolytica* and *Balantidium* sp. are pathogenic, while *Entamoeba coli* is non-pathogenic. *Balantidium* sp. was most prevalent in the study with 39% and 41% in captive and semi-captive respectively. *Entamoeba coli* that is not pathogenic recorded 22% and 32% in captive and semi-captive respectively. Lastly *E. histolytica* with 3% and 35% in captive and semi-captive orangutans.

Protozoan infections in captive orangutans are more severe because of contaminated water and housing according to Munene *et al.* (1998). On the other hand, free ranging orangutans can become infected as well when drinking contaminated water with contaminated fecal material of ruminants, other primates or human. This phenomenon also can be seen in free ranging baboons (*Papio* sp.), which had a lower protozoan infection of *E. histolytica* and *B. coli* in free ranging than captive baboon. However, in captive Sykes monkeys (*Crithagra albogularis*), they showed low infection of protozoa compared to free ranging (Munene *et al.*, 1998). Reversely in free ranging colobus monkeys (*Colobus* sp.) (Gillespie *et al.*, 2005) and free ranging Uganda guenons (*Cercopithecus* sp.) (Gillespie *et al.*, 2004) showed low prevalence of protozoan infections.

Meanwhile in a study comparing wild and semicaptive of ring-tailed lemurs (*Lemur catta*), both wild and captive harbored different parasites species but only protozoa of *Entamoeba coli* was commonly to infect both populations. In captive ring-

tailed lemur, *Giardia* were presents with no clinical symptoms of all, and wild showed positive infection for *Cryptosporidium* (Villers *et al.*, 2008).

2.6.3 Soil parasites

Gastrointestinal parasites could be done by observing clinical signs of the symptoms and using several detection methods such as FAffa MAlan CHArt (FAMACHA) evaluations, larvae cultures and enzyme-linked immunosorbent assay (ELISA) test. Anthelmintic treatment provide prompt solutions to gastrointestinal parasites but, this do not reduce the chance of re-infection to occur if they are kept in infested area. Animals with terrestrial behavior has higher parasite infection by been exposed to the widespread and rapid selection of multirugresistance populations of parasites (Mello *et al.*, 2006; Niciura *et al.*, 2012).

Parasites larval count from pasture sample can determine monthly and seasonal variations of pasture infestation, and also providing an index of the parasite risks to animal that currently inhabit the particular area (Almeria and Uriarte, 1999; Stromberg and Averbeck, 1999). Pasture larval count technique can assist in determining the correct parasite life cycle and other epidemiology data. Kates (1950) published the survival rate of free-living stage larvae *Haemonchus* sp. to be 10 weeks and *Trichostrongylus* sp to be 12 weeks in the summer season in United States.

Besides that, parasites in pasture easily desiccated and influenced by rainfall amount as reported by O'Connor *et al.* (2008), which reported that evaporation rate plays a significant role on the success of *H. contortus* transmission. Third stage larvae can die by the exhaustion of energy reserves occurs more rapidly and fast energy

expenditure in dry conditions. In addition, larvae can survive on a very low level of rainfalls, if only the temperatures are not too high. This shows that larvae need adequate water availability rather than levels of rainfall (Fox *et al.*, 2012).

A drop of rainfall may transport and disperse the larvae as far 90 cm away from the fecal source on the ground. In another study, Uriarte and Gruner (1994) documented that little amount of water facilitated the larvae onto the herbage but huge amount of water transported the larvae into the soil. On another hand, Besier and Dunsmore (1993) concluded that relative humidity and rainfall amount were poor measurement of moisture but pasture greenness are and can be used as qualitative indicator of moisture and larvae survival in Western Australia. Gazda *et al.* (2009) found that larvae rate were heighten during the fall and winter but not during warmer seasons. According to them, eggs of *Trichostrongylus* sp., *Ostertagia* sp., *Cooperia* sp. and *Nematodirus* can survive colder temperature than *Haemonchus* sp. does.

Silva *et al.* (2007) evaluated the rate of third stage larvae present in pasture soil and concluded that it is important to deeply understand the ecology and epidemiology of larvae with correlation to climatic conditions from each different region because climate gives direct influence on the development and survival of free-living stages. Hence, the knowledge of gastrointestinal parasites dynamics on pasture over time can provide useful information to recommend control strategies to the conversation center and consequently can reduce infection of animals living in the area (Almeria and Uriarte, 1999).

2.7 Geographic and climatic features of Malaysia and their relationships with parasitic distributions

Malaysia is a country that covers 329,758 km² area and located between the geographical coordinates of 2° and 7° north and 100° and 119° east. The land composed of two landmasses Sabah and Sarawak on the east and Peninsular Malaysia on the west. Peninsular Malaysia covers 39.9% and Sabah Sarawak covers 60.1% of the total land area. Both of these landmasses were separated by the South China Sea. In the north, Peninsular Malaysia shares a border with Thailand, while Singapore in the south. Sabah and Sarawak share the same border with Brunei in the north and Indonesia Kalimantan province in the south (Nordin *et al.*, 2007).

Malaysia has a climate that categorized as equatorial, being humid and hot throughout the year. The climate features are copious rainfall, high humidity and uniform temperature. In lowlands recorded temperature varies 21 and 32 °C, while in highlands varies between 15 and 25 °C. Total annual rainfall ranges from 2000 to 2500 mm. Average humidity is 80% a year. The climate on both landmasses are different. The climate in the Sabah and Sarawak is more maritime weather whereas wind from the mainland directly affects the climate on the Peninsular (Nordin *et al.*, 2007).

Malaysia has two types of monsoons seasons which are the Northeast and Southeast monsoons. The Northeast monsoon started in November and end in March, and having copious rainfall. Southeast monsoon on the other hand started in May and end in October, and having little rainfall to northwest part of the Peninsular Malaysia. The climate in Malaysia is affected by its topographical features. The coastal regions have a sunny climate, with temperature varies from 23 to 32 °C. The highlands have a

cloudy climate with higher temperature variation and humidity levels over 75%. The lowlands have very high humidity levels and a distinctive rainfall pattern (MMD, 2008; Nordin *et al.*, 2007).

There are three main types of seasonal rainfall variation exist in Peninsular Malaysia which firstly is the period from November to January experiences maximum rainfall in the east coast states, whereas June and July are the driest months. Second, which has two periods of maximum rainfall exist over the rest of Peninsular Malaysia (exception of the coasts in the southwest). The primary maximum rainfall period is from April to May, whereas the secondary maximum rainfall periods are separated by two minimum rainfall periods. The primary minimum rainfall period is from January to February, whereas the secondary minimum rainfall period is from June to July. Lastly, over the southwest regions, the double maximum and minimum pattern is not distinguishable. Maximum rainfall occurs in October and November, with February experiencing the least rainfall.

The one limiting factor of seasonal phenology, individual physiology and population dynamics is the natural climatic regimes that animal and plants experience in their geographic distribution (Kochmer and Handel, 1986). Changes in climate local and globally have altered the trophic interactions and community properties such as species decomposition and structure. Not only that, it also affects the processes to both individual and population level (Morin, 1999; Hughes, 2000; Walther *et al.*, 2001, 2002; Dillon *et al.*, 2010).

Observations and documentations have proved that negative consequences of climate-change have increased the number of habitat disruption, range shift and species

extinction (Altizer *et al.*, 2007; Beaumont *et al.*, 2011). In addition, global warming has been associated with disease risk outbreaks (Rohr *et al.*, 2011). Interaction of climate change and host-parasite interactions have lengthened the parasite reproductive season and create the opportunities for the invasion of a severely disease to occur. Moreover, it also facilitates the transmission disease into naive host populations (Harvell *et al.*, 2002; Dobson *et al.*, 2006; Johnson and Thieltges, 2010; Keesing *et al.*, 2010).

Studies from recent decades have showed evidence of the prevalence and intensity of helminthes has increased in wildlife and livestock from temperate and subarctic latitudes. This occurrence frequently explained as result of general global warming of the particular area (Kenyon *et al.*, 2009). Furthermore, development and survival of helminthes with free-living stages influenced by the climatic conditions where cold and heat stressors they can tolerate (Wharton, 2002).

Previous study also has documented that egg hatching and larval development of soil-transmitted helminthes were accelerated in warmer temperature, but excessively high in values will negatively impact their survival (Saunders *et al.*, 2002). Furthermore, Paull and Johnson (2011) have explicitly addressed the role of climate warming on parasite dynamics. In contrast, how they respond to daily seasonal and long-term changes remains poorly understood.

2.8 Anthelmintic drug of parasites

Anthelmintic drugs are chemical substances that destroy and eliminate helminths from the body of infected human or animals by either killing or stunning them. Even up to this day, anthelmintic drugs is a preferred means of parasitic worm control in the world (Buihol *et al.*, 2011; Jackson *et al.*, 2009; McArthur *et al.*, 2011; Waller, 1993).

Two centuries ago, medicines containing metal of iron and tin, and plants with toxic effects were used to the worms that infect intestinal parasites. This mechanism involved in using this treatment is by removing the mucous of bowel lining, so that the worm is difficult to latch on it, or give irritation to the parasites from staying on its resting sites. Parasite treatments in the late 19th century changed to chemical compound as nicotine sulphate, copper sulphate, arsenic and carbon tetrachloride became available in large quantity, through synthetic chemical production. These compound in contrast did not heal parasite infection due to its high toxicity that affect the animal health and ineffective against parasites (McKellar and Jackson, 2004).

In 1940, first broad-spectrum anthelmintic drug against parasitic worms, phenothiazine was introduced. Later, piperazine in 1954 and bapfenium in 1959 were introduced. All three drugs worked well against specific target species, with some documented giving side effects to the ruminants. Between 1960 and 1980, broad-spectrum drugs such as benzimidazole, imidazothiazoles and macrocyclic lactones were available in the market. These newly introduced drugs at that time had significantly lower dose rates (measured in milligrams per kilogram of body weight) than earlier compound introduced (measured in grams per kilograms of body weight) (Kohler, 2001; McKellar and Jackson, 2004).

Gastrointestinal parasites infecting wild orangutans are often documented compared to semi-captive orangutans because semi-captive orangutans often treated with anthelmintics as preventive strategy (Munene, 1998) such as ivermectin that usually been used routinely to kill gastrointestinal parasites. In contrarily, the limitations of anthelmintic use are resistance (Echevarria, 1996), drug residues in food (Padilha, 1996) and eco-toxic effects (Herd, 1995). Hence these various availability control measures should be organized into an integrated program to ensure maximum efficiency (Waller, 1998) with minimal use of the available compound.

Ivermectin and mebendazole have been frequently used to control gastrointestinal nematodes of nonhuman primates in clinical application because they are highly effective, broad-spectrum and safe (Karr *et al.*, 1978; Brack and Rietschel, 1986; Wade *et al.*, 2006). The following sections will focus on two main classes of anthelmintic drugs used on orangutans in the conservation center.

2.8.1 Benzimidazole

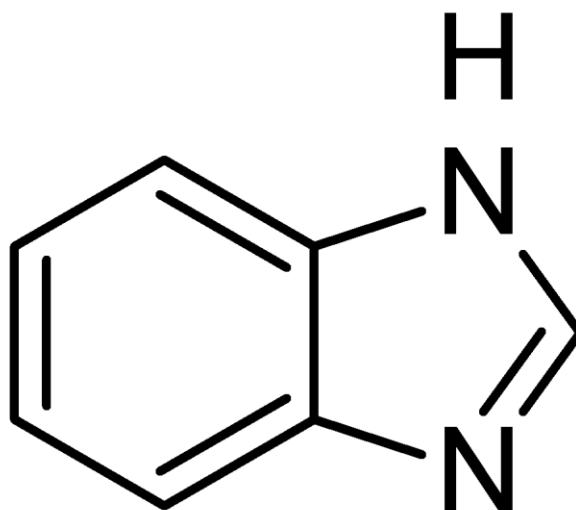


Plate 2.5. Benzimidazole simple chemical compound structure

(Source:

<https://www.sigmaaldrich.com/catalog/product/aldrich/194123?lang=en®ion=MY>)

Benzimidazole (Plate 2.5) is released after the first-generation phenothiazine and piperazine making it's the second-generation of broad spectrum anthelmintic drug. Benzimidazole is a combination of benzene and imidazole and a heterocyclic aromatic organic compound. It was introduced in 1961 through thiabendazole as the first broad spectrum anthelmintic drug. Benzimidazoles used to treat roundworm (nematode) and fluke (trematode) in small ruminants and comprises a large family of broad-spectrum drugs. This drug family such as thiabendazole, albendazole, oxfendazole, mebendazole, fenbendazole, flubendazole, triclabendazole, oxibendazole and febantel are potent members with wide safety margin (Kahn *et al.*, 2006; Kohler, 2001). The most effective

drug family are albendazole, oxfendazole and fenbendazole because they have long half-life. Since they are slowly metabolized, the concentrations in plasma and gut can be maintained for long periods effectively. This increased their efficacy against immature adult nematodes (Holden-Dye and Walker, 2007; Kohler, 2001).

2.8.2 Macrocyclic lactones

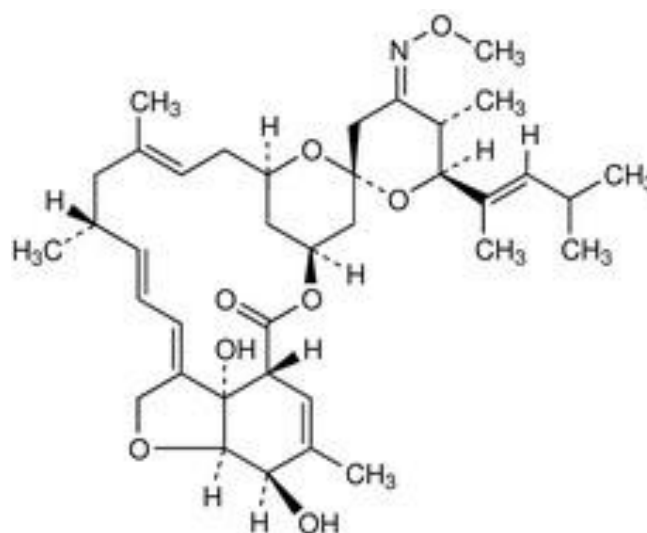


Plate 2.6. Macrocyclic lactones chemical compound structure

(Source:

https://parasitipedia.net/index.php?option=com_content&view=article&id=2413&Itemid=2678)

Macrocyclic (Plate 2.6) lactones were introduced in late 1970s as anthelmintic by a United States pharmaceutical company Merck. Their members are milbemycins and avermectins. They are derivatives of a by-product of fermentation by *Streptomyces avermitilis* of the actinomycetes genera of soil microorganisms. Ivermectin is a derivative of avermectin and was introduced in 1981 (James *et al.*, 2009). Ivermectin is a broad-spectrum drug at low dose levels with high safety and effective on many